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ELECTROMAGNETIC CODE CONSORTIUM BENCHMARKS

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Final Report

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14. ABSTRACT
Several additions to the metallic Electromagnetic Code Consortium (EMCC) benchmarks are described. The new geometries include a cube, a prism, a pyramid and a trihedron. These geometries include edge, corner, and multipath scattering effects. In addition, the first EMCC antenna benchmark composed of an array of elements on a finite metal plate is described. Measured and computed scattering or radiation data for each new geometry is shown. Computed data is generated with the FISC, AIM, and XPATCH codes. Where applicable, sources of discrepancy between the measured and computed results are discussed. For some of the objects, the measured data is taken in two passes to improve the dynamic range. However, at present only one pass of the data is available, resulting in some error near the top or the bottom of the data range.

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1 Introduction

The electromagnetic code consortium (EMCC) is a joint organization sponsored by the US Air Force, the US Army, the US Navy, and the National Aeronautics and Space Administration (NASA) whose purpose is to advance computational electromagnetic (CEM) code development. To this end, the consortium collects and distributes data for benchmark CEM problems. Previously published EMCC benchmark data appears in [1], [2]. The new proposed problems include scattering targets with edges and corners and multi path effects. Some of the geometries are electrically large. Also, the first EMCC antenna benchmark is included.

2 NRL Problems

The first three problems are submitted to the EMCC by the Naval Research Laboratory (NRL). The geometries include a cube, a prism, and a pyramid. The measured data from NRL is collected in two passes with different levels of attenuation on the measurement equipment. This is done to improve the dynamic range of the data. However, due to data release problems at NRL, only the low attenuation data is available in most cases. This results in some clipping error near the peaks of the radar cross section (RCS) in a few of the plots in this report. In spite of this acknowledged error, it is believed that much of the available of the data is useful for code validation purposes. A follow up report is planned when the remainder of the data becomes available.

2.1 Cube

The cube is shown in Fig. 1. It is a high precision target, and it is a good canonical shape for code validation. Each side is one meter in length, and the edges are ground sharp. The RCS of the cube as a function of azimuth angle at 0° elevation for 0.43 GHz and 1.3 GHz is shown in Fig. 2. The error near the peak of the 1.3 GHz, VV-polarized result is caused by clipping in the measurements, as discussed in the introduction to Sec. 2. The computed results in Fig. 2 are generated with the Fast Illinois Solver Code (FISC). The 0.43 GHz results are generated using 2304 unknowns and 362 right hand sides in 17.6 minutes on a SUN Ultra-60 processor, and the 1.3 GHz results are generated using 18432 unknowns and 362 right hand sides in 4.84 hours on a single SUN Ultra-60 processor.

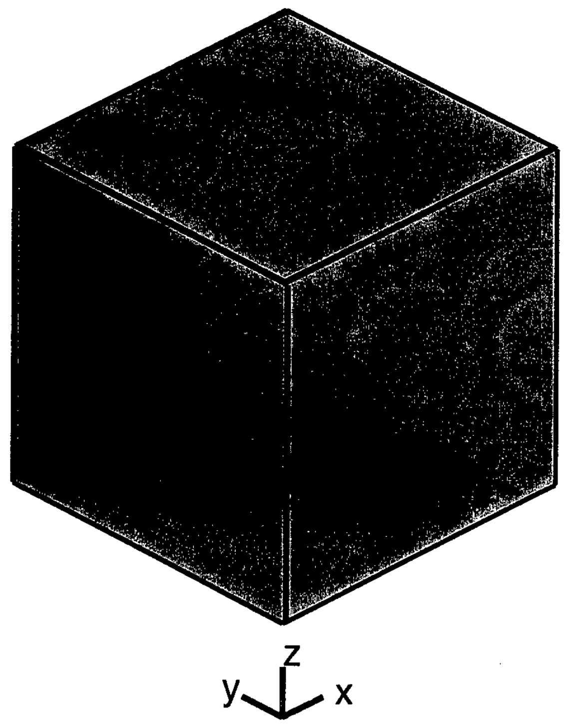
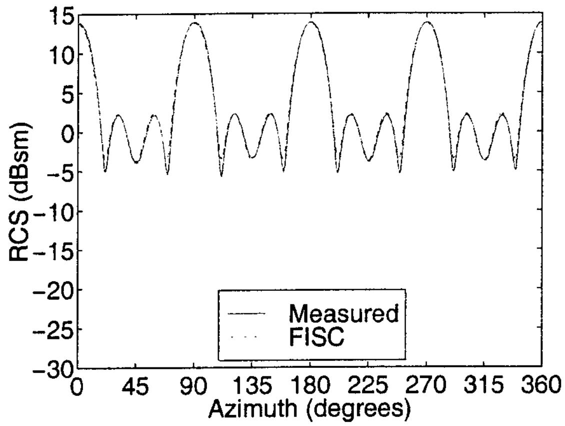


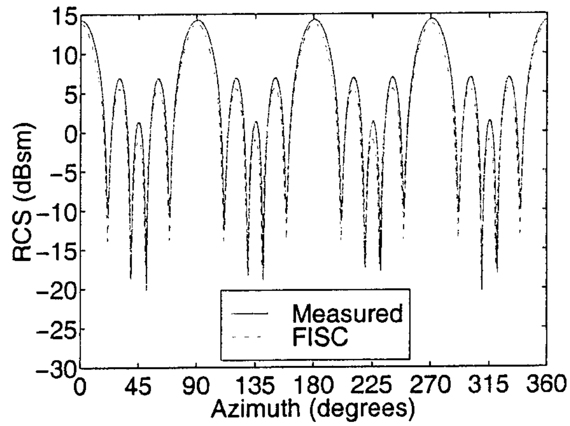
Figure 1: Picture of the cube.

2.2 Prism

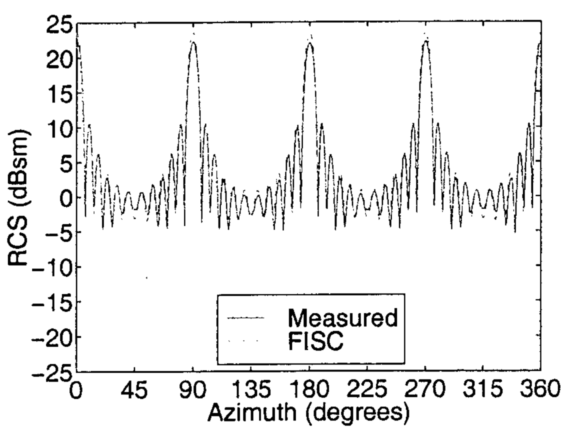
The prism is shown in Fig. 3. The purpose of the prism is to capture traveling wave effects for three different wedge angles. The sides are 94.83 cm, 178.24 cm, and 240.13 cm in length, resulting in wedge angles of 20°, 40°, and 120°, and the thickness is 30.48 cm. The edges are sharp. The RCS of the prism as a function of azimuth angle at 10° elevation for 0.43 GHz, 1.3 GHz, and 9.2 GHz is shown in Fig. 4. The error near the peaks of some of the plots is caused be clipping in the measurements as discussed in the introduction to Sec. 2. The computed results for 0.43 GHz and 1.3 GHz are generated by FISC, and the 9.2 GHz results are generated using the high frequency shooting and bouncing ray (SBR) code xpatch. The 0.43 GHz results use 1140 unknowns and 1442 right hand sides and require 49.6 minutes on a SUN Ultra-60 processor, and the 1.3 GHz results use 11904 unknowns, 1442 right hand sides, and 26.7 hours on a SUN Ultra-60 processor. The high frequency 9.2 GHz results are sampled every 0.2° and first order edge diffraction is included; these results are generated in 35.8 minutes on a SUN-Ultra-60 processor. Note that traveling wave effects are not included in the high frequency SBR approximation; thus, the computed results are lower than the measurements in regions of low RCS.



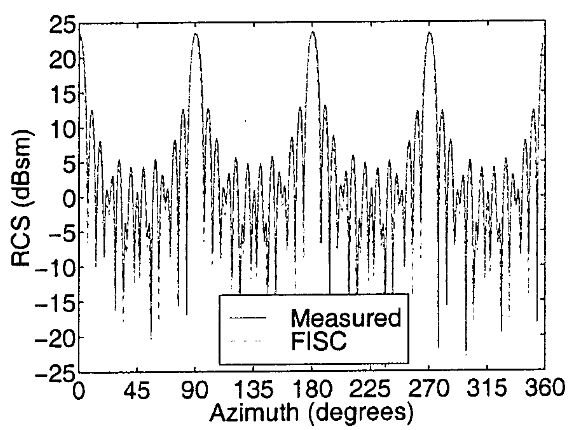
(a) 0.43 GHz, VV-polarized



(b) 0.43 GHz, HH-polarized



(c) 1.3 GHz, VV-polarized



(d) 1.3 GHz, HH-polarized

Figure 2: RCS of the cube at 0° elevation for 0.43 GHz and 1.3 GHz. The error near the peak of the 1.3 GHz, VV-polarized result is caused be clipping in the measurements as discussed in the introduction to Sec. 2.

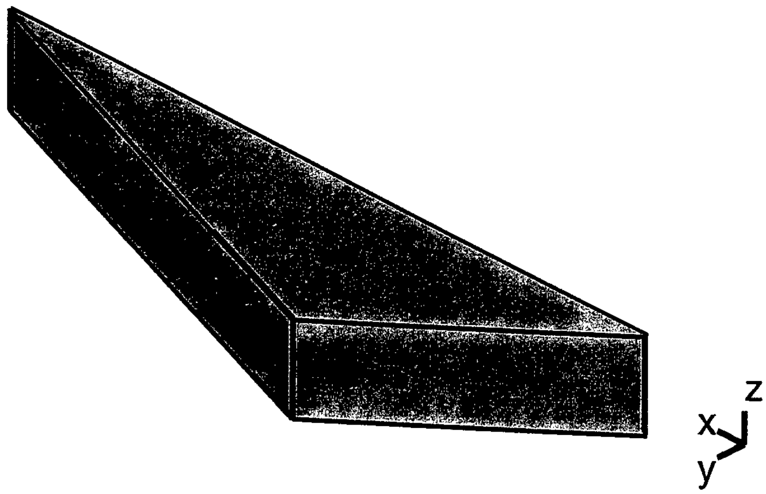


Figure 3: Picture of the prism.

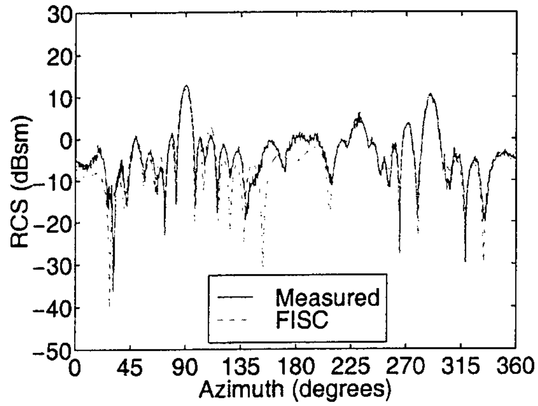
2.3 Pyramid

The pyramid is shown in Fig. 5. Its base (surface in the $x - y$ plane of Fig. 5) is a triangle with sides 32.41 cm long, and its height from the center of the base to the opposite vertex is 33.20 cm, resulting in side lengths of 38.10 cm from the corners of the base to the vertex opposite the base.

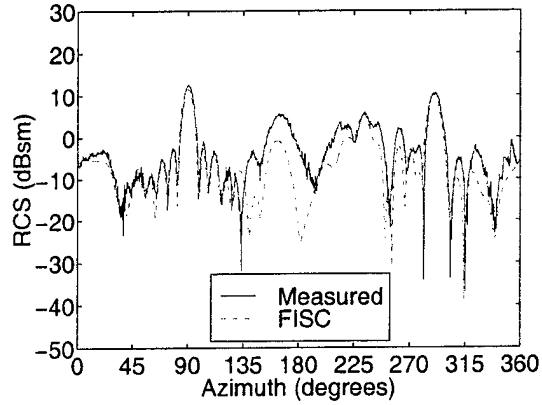
To create multi path results, the pyramid is measured at 9.2 GHz and 16° elevation on a metalized bounce plane. (The bounce plane corresponds with the $x-y$ plane.) Unfortunately, the VV-polarized measured data for the pyramid has a very high noise floor, but the HH-polarized data is somewhat better. Measured results and computed results generated with the EMCC code AIM are shown in Fig. 6. The computed results used 53985 unknowns and 1442 right hand sides and required 78 hours on 11 SGI Origin 2000 processors. There is apparently some measurement error or error in construction of the target as evidence by the peak shift near 120° azimuth in both polarization plots in Fig. 6.

3 Trihedron

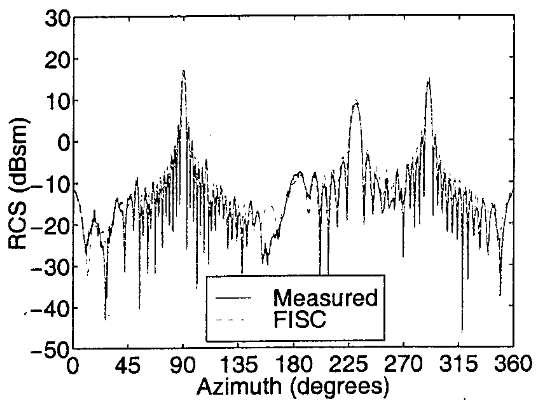
The trihedron is submitted to the EMCC from the National Ground Intellegence Center. The geometry with relevant dimensions is shown in Fig. 7. Electromagnetic scattering from this target includes multiple interactions, surface waves, and edge waves. The measured and computed (using FISC) RCS at 10° elevation, 0°-90° azimuth, and 10 GHz are shown in Fig. 8. The computed results used 619587 unknowns and 362 right hand sides and required 98 hours on 24 SGI Origin 2000 processors. Note that the thickness of the plates is not included in the geometry description available for generating computed results. Thus, the



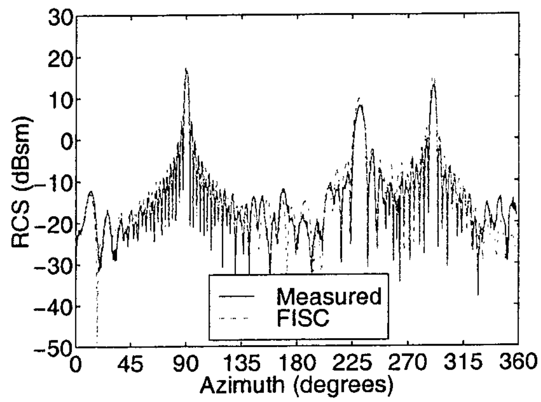
(a) 0.43 GHz, VV-polarized



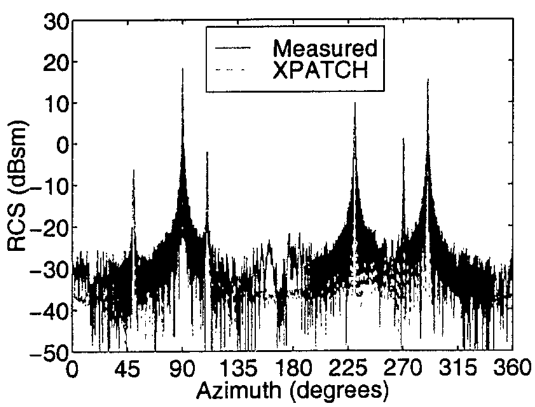
(b) 0.43 GHz, HH-polarized



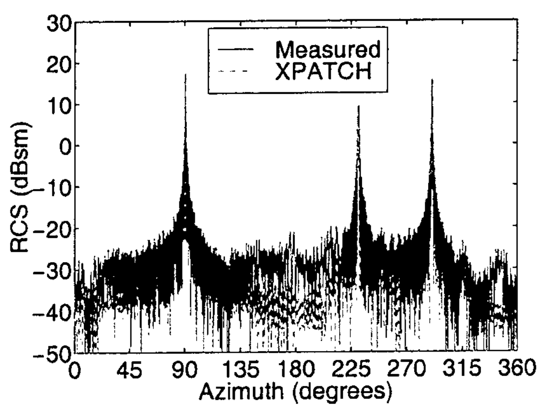
(c) 1.3 GHz, VV-polarized



(d) 1.3 GHz, HH-polarized



(e) 9.2 GHz, VV-polarized



(f) 9.2 GHz, HH-polarized

Figure 4: RCS of the prism at 10° elevation for 0.43 GHz, 1.3 GHz, and 9.2 GHz. The error near the peaks of some of the plots is caused be clipping in the measurements as discussed in the introduction to Sec. 2.

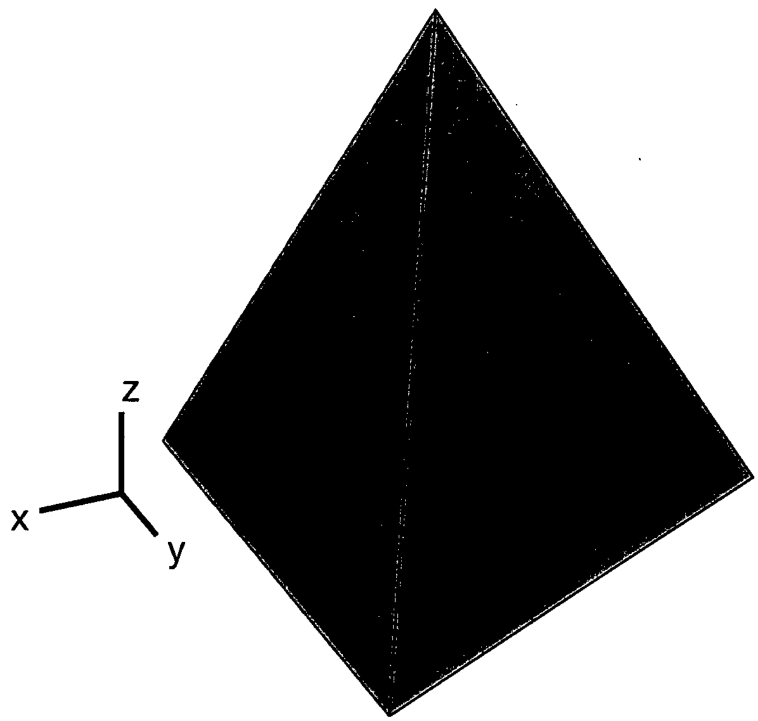
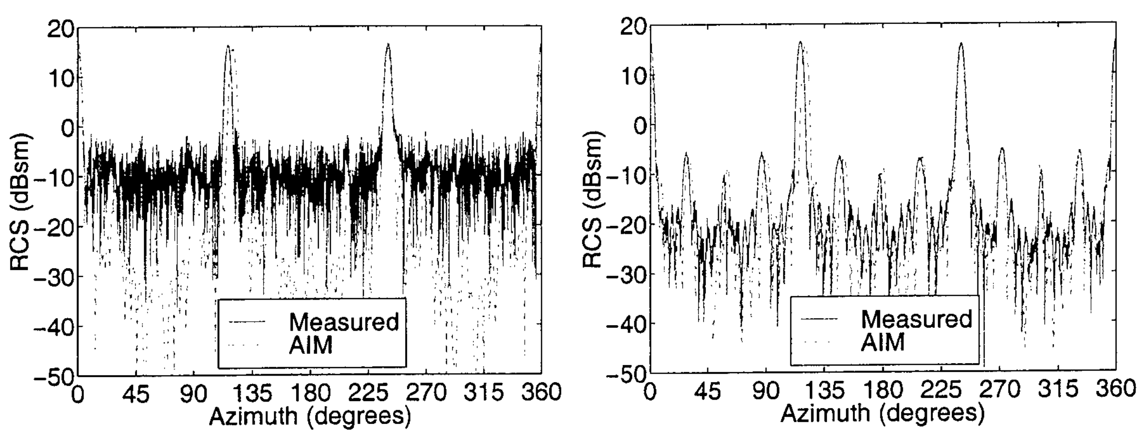


Figure 5: Picture of the pyramid.



(a) VV-polarized (b) HH-polarized

Figure 6: RCS of the pyramid on a metal bounce plane at 16° elevation and 9.2 GHz.

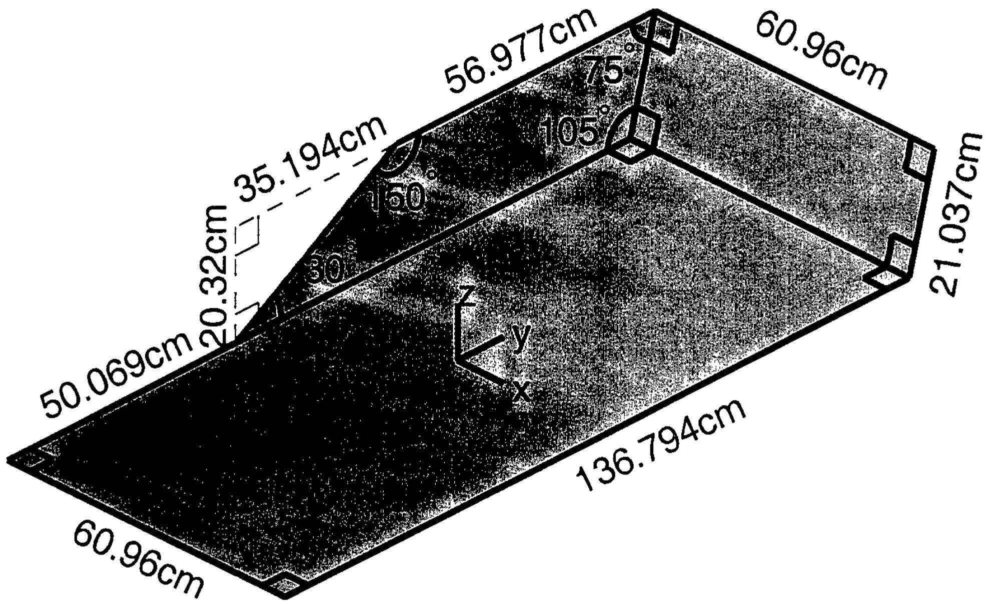
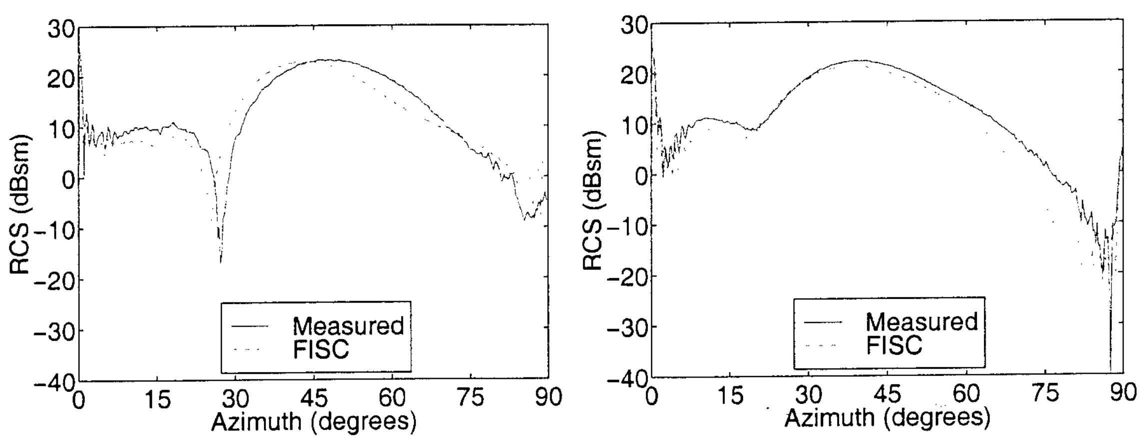


Figure 7: Picture of the trihedron with relevant dimensions. Note that the bottom plate is parallel to the $x-y$ plane; the left plate is parallel to the $y-z$ plane; the back plate is tilted 15° toward the y axis from parallel to the $x-z$ plane.



(a) VV-polarized

(b) HH-polarized

Figure 8: RCS of the trihedron versus azimuth 10° elevation and 10 GHz. The plates in the FISC computations are modeled as 0.3 cm thick.

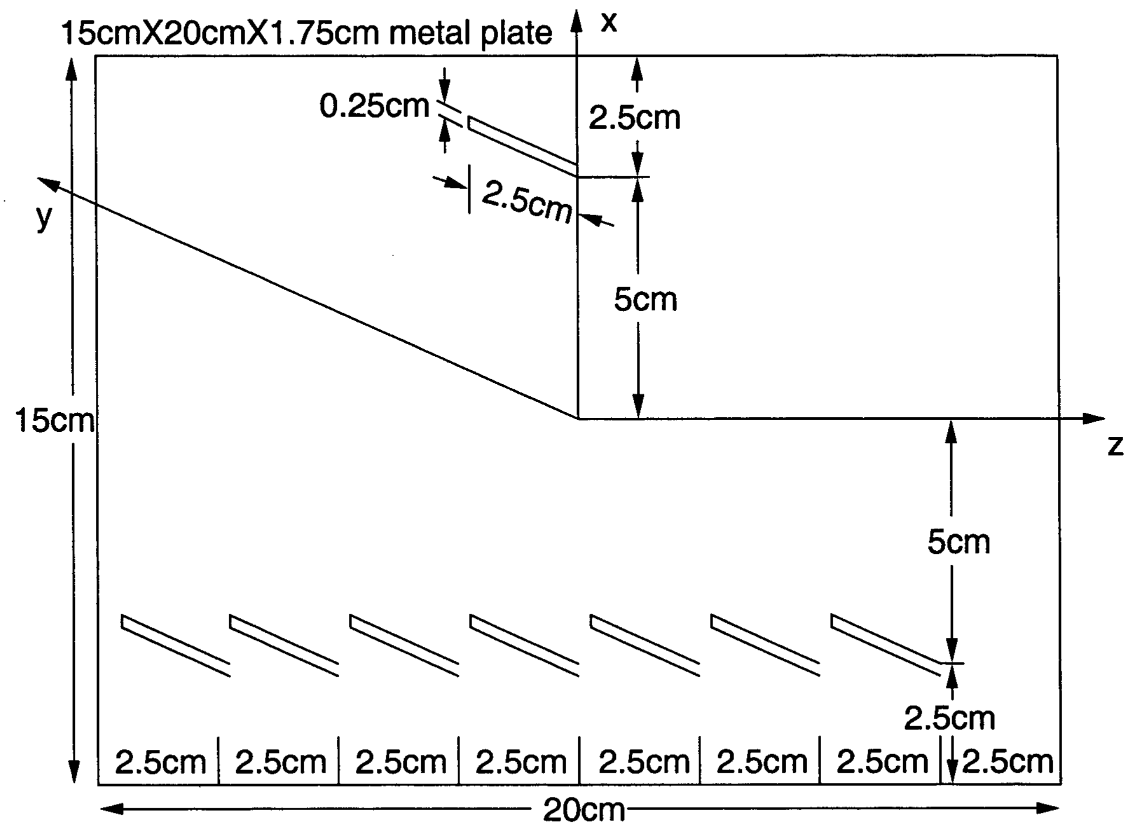


Figure 9: Picture of the antenna array with relevant dimensions. The thickness of the plate is 1.75 cm. The elements are modeled as infinitely thin. The element at top is driven; the others are passive.

plates are arbitrarily assigned a thickness of $\lambda/10 = 0.3$ cm. This is a possible source of error in the computations.

4 Antenna Array

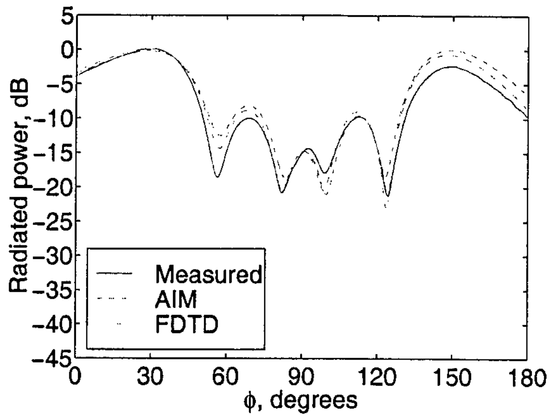
The final benchmark of this report involves the computation of the radiation pattern of an antenna array on a flat plate, which represents the first EMCC antenna benchmark. It is hoped that future benchmarks will include many more antenna problems, including near field problems such as the computation of the antenna input impedance.

The geometry of the antenna array is shown in Fig. 9. In the figure, the elements are modeled as infinitely thin, and the element shown at the top of the figure is driven; the other elements are passive.

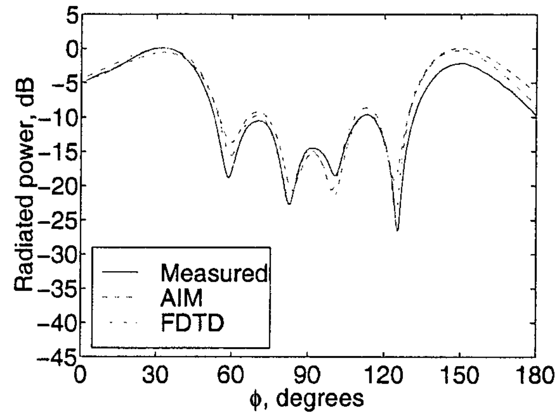
The E-plane pattern of the antenna array is measured at 5 frequencies from 5.3 GHz to 5.7 GHz and shown in dB down from the maximum in Fig. 10. Two computed results are also shown in Fig. 10, one generated from the EMCC code AIM, and the other generated from the TSAR finite-difference time-domain (FDTD) code. The AIM results took approximately 4.5 hours per frequency to run on a SUN Ultra-60 processor, and the FDTD results took approximately 14.2 hours for all 5 frequencies in a single run on a SUN Ultra-60 processor.

5 Conclusion

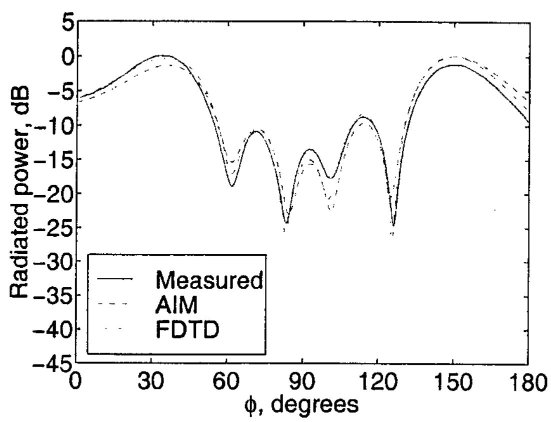
A cube, a prism, a pyramid, and a trihedron are added to the EMCC scattering benchmarks, and an antenna array on a metal plate represents the first EMCC antenna radiation benchmark. Measured data for each case is compared to computed data, and where possible, sources of error are identified. Although some problems are known to exist with the data, it is believed that this data is valuable to the computational electromagnetics community for code testing purposes. In the cases of the cube, prism, and pyramid, measured data improvements (see Sec. 2) are expected in the future, and a follow on report is planned.



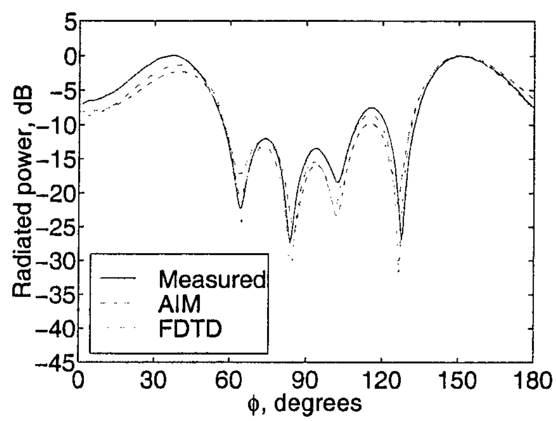
(a) 5.3 GHz



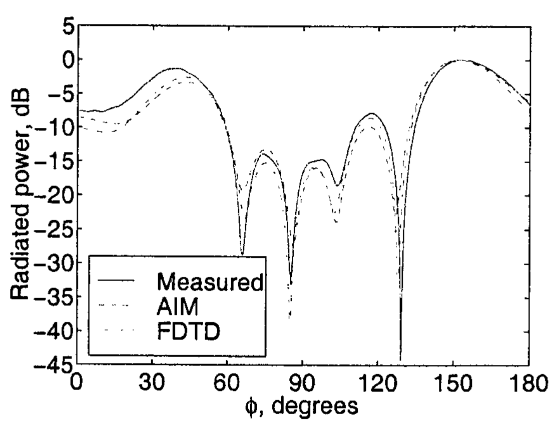
(b) 5.4 GHz



(c) 5.5 GHz



(d) 5.6 GHz



(e) 5.7 GHz

Figure 10: E-plane pattern of the antenna array in dB down from the maximum. The angle ϕ is measured from the positive x-axis.

References

[1] A. C. Woo, H. T. G. Wang, M. J. Schuh, and M. L. Sanders, "Benchmark plate radar targets for the validation of computational electromagnetics programs," *IEEE Antennas Propagat. Mag.*, vol. 34, pp. 52–56, Dec. 1992.

[2] A. C. Woo, H. T. G. Wang, M. J. Schuh, and M. L. Sanders, "Benchmark radar targets for the validation of computational electromagnetics programs," *IEEE Antennas Propagat. Mag.*, vol. 35, pp. 84–89, Feb. 1993.

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